

Forty Sixth CIRP Conference on Manufacturing Systems 2013

Improving changeover time: a tailored SMED approach for welding cells

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Abstract

Short changeover times have always been critical in manufacturing business. Set-up duration reduction initiatives have been associated with Shingo's 'Single Minute Exchange of Die' (SMED) method. Although a great number of companies have initiated SMED, some failed on implementation. The main reason is that strict application of Shingo's SMED methodology is not the most efficient way to reduce set-up times in all situations. In the present study a tailored methodology is presented that has been developed specifically for an automotive supplier. The validation of the proposed method was done through implementation on an industrial welding cell for a period of four months. The main finding is that in addition to SMED tailored methodology, appropriate strategy definition and preparatory activities are key enablers for success. That includes project targets and timescale definition, selection of the appropriate team and coordinator, allocation of specific roles and responsibilities to each team member, training of team and shop floor staff on the new methodology and changeover standards. By implementing the new tailored SMED improvement programme, the company achieved 33% reduction on changeover time.

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Selection and/or peer-review under responsibility of Professor Pedro Filipe do Carmo Cunha

Keywords: Lean manufacturing; SMED; changeover time, set-up time

1. Introduction

The importance of short changeover times has always been critical for manufacturing companies, especially automotive ones. Globalization has developed transport and communication, creating a global market around the world. Nowadays, customers demand a wide range of products delivered with high quality, quicker response times and sold at reasonable prices. To survive in such an increasingly competitive world, there is a need of continuous improvement in every type of industry.

An answer to these challenges for manufacturing companies is the implementation of lean concepts and customer-pull-based production for being capable to satisfy all customer needs. With the same demand as with previous years, companies are forced to produce smaller lots without affecting their global productivity. However, producing more products at smaller batch sizes, results in more changeovers. Thus, a rapid changeover capability is critical for being able to

produce small quantities of a large diversity of products, the basis of a pull production.

Van Goubergen et al. [1] indicated three main reasons why set-up reduction initiatives can be appropriate for any company: to increase flexibility by conducting more changeovers and reducing lot size; to increase bottleneck capacities in order to maximize the line availability for production; and to minimize the cost, since production costs are related to equipment effectiveness.

In the present paper a tailored SMED methodology was developed specifically for an automotive supplier and validated in one of his welding cells.

2. Reducing Changeover Time: The SMED approach

"Changeover time" is defined as the period between the last good product from previous production order leaving the machine and the first good product coming out from the following production order [2, 3].

Most initiatives for set-up reduction time have been associated with Shigeo Shingo's "Single Minute Exchange of Die" (SMED) methodology [4]. SMED was

proposed as a workshop improvement tool focusing on low cost proposals with a kaizen improvement basis, involving shop floor teams [5]. Later on, the evolution of Toyota Production System contributed to the spreading of the methodology around the world [6].

Shingo claimed that SMED is “a scientific approach to set-up time reduction that can be applied in any factory to any machine”. With regards this statement, many studies are focusing in its applicability to other types of factories and machines [7].

Shingo [4] bases his method on categorizing all setup activities into internal and external ones. With internal activities being the ones that can be performed only when the machine is shut down, and external being those that can be conducted during the normal operation of machine, when it is still running. These internal and external set-up activities involve different operations, such as preparation, after-process adjustment, checking of materials, mounting and removing tools, settings and calibrations, measurements, trial runs, adjustments, etc.

SMED methodology is formed by four single stages [4]; a preliminary stage where the internal and external set-up conditions are not distinguished; the first stage where separating internal and external set-up takes place; the second stage where internal activities are converted to external ones; and finally the third stage focusing on streamlining all aspects of the set-up operation.

The application of Shingo’s methodology usually results into two main benefits: increasing manufacturing capacity and improving the equipment flexibility [3]. That allows working with smaller batch sizes, creating a flow of materials by eliminating waiting.

Both benefits are translated into cost reduction. The Economic Order Quantity (EOQ) model [3] explains how SMED can help reduce cost by lot size reduction. EOQ is defined as “the lot size that minimizes total annual cycle-inventory holding and ordering costs” (fig. 1). In a production environment, total inventory costs are related with holding work or keeping items on hand (storage, insurance, handling, etc.). Ordering costs are related with equipment efficiency, being affected directly by changeovers due to time losses.

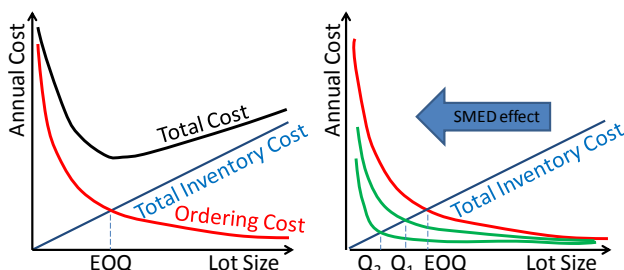


Fig. 1. Economic Order Quantity and SMED effect on reducing ordering cost due to change-over time reduction [3]

Although SMED is known for more than twenty five years and many examples are reported on successful initiatives, a number of companies have failed on implementation. Few studies have been presented on failing initiatives and the causes of such failures. McIntosh et al. [7] argue that one possible cause of failure might be the strictly application of “SMED” methodology. The four stages pathway might not be the most efficient way to reduce set-up times in all situations. Indicatively, some companies put too much emphasis on transferring changeover internal tasks to external, missing the importance of minimizing or streamlining internal and external activities by design improvements. This problem appears because Shingo’s methodology is mainly focussed on organizational-led-improvements and not focusing enough on equipment design improvements [8]. Organization improvements are focusing on changing the way the people work. In contrast, design based improvements put attention on physically modifying manufacturing equipment [9].

Fig. 2 presents the expected improvement on changeover time depending on the different focus that can be adopted during the SMED implementation. If focus is only on methodology, results can be poor. In contrast, by combining design modifications and methodology improvements, the outcomes can be acceptable with a moderate investment. The design of a new system is out of scope when implementing SMED programmes, although results can be excellent.

It is important to define what success and what failure is on SMED implementations. Some researchers suggest that with SMED it is easy to achieve reductions of up to 90% [1]; however the literature review has not resulted in any descriptive examples proving these ambitious results from real implementation cases.

An important changeover aspect, the run-up period, has been given little attention. McIntosh et al. [7] defines the run-up period as the time when steady state manufacture is being re-established, with optimal productivity and quality rates. Normally it includes activities such as adjustments and quality checking. SMED methodology does not cover the run-up period as part of the changeover reduction strategy.

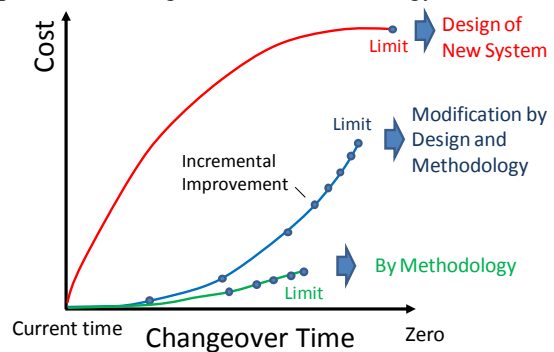


Fig. 2. Limits and costs of changeover improvement strategies [10]

Another shortcoming of SMED method, lies with the fact that it addresses set-ups performed by one operator involving one single machine, when, in practice, there is a need of implementation in manufacturing lines formed by multiple machines and controlled by multiple operators [11]. When a changeover is being run in a manufacturing cell, the SMED methodology is not specific about how the set-up time should be measured.

Finally, although changeover reduction literature is extensive, not adequate attention to team performance during SMED programmes is being given. SMED improvement programme should involve the process identification and changeover analysis, the training of the improvement team, as well as selecting the appropriate members and their responsibilities during the project. The training they receive and their motivation can be a major driver for success [2]. Such training can facilitate success when it is provided to both the SMED team and the shop floor staff involved with the implementation. This training can reduce staff hesitation and fears arising from misunderstanding [1].

With regards shop-floor staff and especially operators, the importance of sustaining the improvements has received little attention. The only way to sustain the improvements is by standardizing and controlling the new methodology, as well as continuous monitoring of all the set-up times [7, 10].

It is obvious that Shingo's SMED methodology by itself cannot guarantee successful outcome without considering some other aspects that affect changeovers. To summarize, the run-up and run-down periods, the appropriate team to be involved on the initiative, the definition of achievable targets, the type of industry and machine where SMED is going to be implemented, the focus of the initiatives (organizational or hardware improvements) all of them are issues than should be considered in every changeover initiative.

3. Proposed methodology

In order to overcome the shortcomings discussed in the previous section, the improvement project should be divided into four phases: strategic, preparatory, implementation and control. Such an improvement route can be used to separate activities and allocate people to tasks, forcing the progress to occur in an optimal sequence. SMED tailored methodology is under the implementation phase.

The four stages model is inspired by McIntosh et al. [9] overall methodology for changeover improvements. However, one significant difference to McIntosh work is that the control phase is considered a separate step for checking that improvement results meet the team and senior management expectations.

- Strategic phase.

For a changeover improvement project to be successful, a number of aspects have to be considered in advance for defining the appropriate strategy. To start with, the senior management rational for proposing a changeover improvement initiative in a specific area should be clear, as well as the level of improvement required (target) and the timescale [9].

Secondly, there is a need of project management to achieve the targets or goals defined. Thorough planning is needed explaining how the different activities are going to be organized, and setting deadlines for each task. The planning should also include how the progress is going to be monitored and controlled [12].

At this phase alternative options should be also considered as whether they would be better than improvement initiatives for reducing changeover times, for instance to purchase new equipment [9].

Subsequently, it should be decided if emphasis would be on low-cost organizational improvements or design improvements [9]. Such a decision depends on the level of improvement required and the budget available for the project. Fig. 2 indicates the limits and costs of both changeover improvement strategies. High expectations might be managed with focussing on both pathways.

Finally, for the optimum implementation of SMED, a review of literature should be undertaken for adopting best practices. A new tailored SMED methodology is proposed in the following section resulting from the analysis of the state of the art.

- Preparatory phase

The people to be involved in a changeover initiative should be analysed carefully. Krajewski et al. [12] mention the need of a project manager with the appropriate skills for driving the project during the timeline defined. Every project manager should play three roles in any project: facilitator, communicator and decision maker [12].

The selection of project team is another decision to be made carefully. Team working is especially significant in such a project because a variety of people have to be involved. Krajewski et al., [12] and Coimbra [3] suggest forming the team with people from different departments across the organization. In a manufacturing changeover initiative team should include people from the shop floor, maintenance, logistics, engineering department, lean department and senior management. Senior managers should be included as they have a crucial role in ensuring that momentum is maintained [9]. With regards team members, Krajewski et al. [12] mention technical competence, sensitivity and dedication as the most important characteristics that members should poses in any project team. But these skills do not guarantee teamwork success. McIntosh et al. [9] argues that attitude, awareness, resources available and team

direction are also key components for teamwork success on delivering the targets defined.

Belbin Roles theory [13] can be used as a reference to assemble the team and allocate roles and responsibilities. Such an approach assures that requirements posed by their role are met in the best way and by the best possible team member. Belbin proposes nine roles, each of them with a distinct and necessary contribution to team performance. For each role, there are strengths and weaknesses, so the right balance between them is key. Those roles are driven by three main categories: they can focus on ideas, tasks or people. Each role makes a different contribution to each domain depending on the role characteristics. But all of them together make a good balance for teamwork success.

Another key issue for the success of such initiatives is the training of the team and the supporting shop floor staff. Goubergen et al. [1] proposes training as a good way to motivate the staff that will be involved in the project, particularly those who will perform the changeover standards resulted from the study. Team members, as well as shop floor staff should get training on the overall methodology for changeover improvement before any workshop session [9]. The focus of training should be placed also on changing the attitude into a work place improvement culture or “kaizen” culture [14].

Once the team has been assembled and trained, one of the first activities is the analysis of changeover performance, the assessment of the quality and accuracy of the available data (changeover performance records) [9]. In many cases it may be needed to collect data with higher accuracy. Automatic systems to register data can be considered, as they are always more reliable, however they are not efficient on motivating shop floor teams.

Finally, within the preparatory phase, a good communication framework needs to be established between the different team members, senior managers and shop floor operators. It is essential to consider how the information is flowing from improvement team to the rest of the company. This can be achieved through a Plan, Do, Check, Act (PDCA) panel ideally located in the shop floor, to be updated frequently.

- Implementation phase.

Within the implementation phase, a number of workshop sessions should be scheduled for implementing the SMED methodology. These sessions should follow the five stages route that is explained in the following section and presented in fig. 3.

- Control phase.

During the control phase, the focus should be on monitoring the key performance indicators, with the changeover time being the most important one. Additionally, economic figures can be derived for further promoting the initiative. Furthermore, according

to continuous improvement philosophy, an action plan can be placed for registering new ideas for reducing changeover time.

4. Proposed tailored SMED method

The proposed SMED methodology is based in McIntosh et al. [9] overall methodology for changeover improvements and Shingo’s SMED methodology [4]. It consists of 5 stages (fig. 4):

- Stage 1: Classify activities into External, Internal or to be eliminated.

During the first stage, all activities have to be classified based on whether they can be executed while the machine is working or not. These activities can be categorized using video recordings and routing diagrams. Shingo [4] suggests interviewing shop floor staff for collecting improvement ideas.

Furthermore “set-up period”, “run-up period”, and “run-down period” must be distinguished. The run-up period starts when parts of product B are coming out the process, but steady production and full capacity have still not been achieved. A common mistake is to select set-up period (when machine or line is stopped) as the changeover duration for SMED implementation. The best way to avoid confusion is to use the definition of changeover time given at the beginning of section 2 [8].

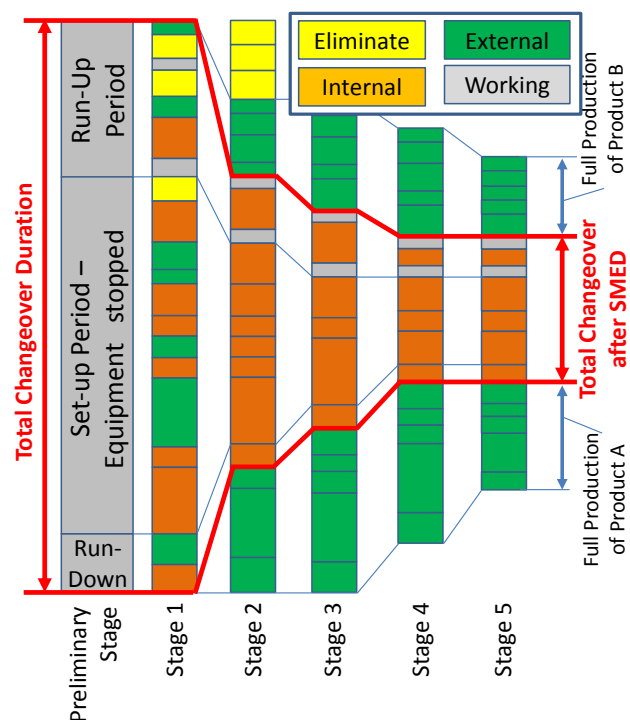


Fig. 3. Proposed tailored SMED methodology

- Stage 2: Separate External work and Internal Work.
Eliminate activities that are not necessary.

External work has to be moved either at the beginning or the end of the changeover. Two options are considered for achieving it: Either organization and distribution of all external activities among operators involved in the changeover, resulting in external work remaining as it was. Alternatively, all external work can be allocated to one specific operator called “external operator”. This can minimize waste by assigning movements and transportations in one single person.

After external work has been separated, internal work must be standardized, trying to balance tasks between different operators involved. Additionally, activities not required can be directly eliminated. Appropriate training is critical for achieving good results after this stage. Operators have to be trained on the new changeover methodology. Coimbra [3] highlights standards and training as key elements for success.

Some techniques suggested by Shingo include [4] setting checklists for guaranteeing that external activities are performed before changeover starts, and establishing function checks. Additionally, layout analysis might be useful in combination with a 5S programme, to set in order all the elements necessary for the changeover. Dies, tools, and raw materials must be as close as possible to work area before changeover starts.

- Stage 3: Convert Internal work into External work.

According to Shingo [4], this stage involves two significant activities to be performed by the improvement team: the detailed analysis of internal operations to detect wrong assumptions, and the research of different ways to convert these activities into external work. Tools standardization and the use of intermediary jigs are some techniques that support this stage [1, 4].

- Stage 4: Streamline and reduce internal work.

At this stage, all the effort is placed on optimizing all internal tasks. Some technical principles can be applied in order to reduce duration of internal activities. Shingo mentioned some possible options to achieve this [4] such as implementing parallel operations, using functional clamps, increasing mechanization of different machine components, reducing adjustments to minimum and designing effective tools to help on internal tasks.

This step is time consuming and usually requires medium to high cost implementation ideas. It is necessary to evaluate the benefits of each proposal carefully to discard ideas that would not improve changeover time significantly.

- Stage 5: Streamline and reduce external work.

This stage is the main difference of the tailored to industry SMED methodology to Shingo’s one. Stage 5 is the result of splitting third Shingo’s stage [4] into two separate phases. The purpose of this modification is to

concentrate all resources on reducing internal times prior to streamlining external work. Reducing external work does not affect the changeover time, as all activities are performed before and after the line has stopped. However, added value is gained when reducing internal time. Many companies focus on reducing duration of external activities with no results in changeover times.

5. Implementation

The proposed tailored SMED methodology was tested and implemented in a tier 1 automotive supplier in one of its welding cells (fig. 4). Within this company the number of changeovers had increased (from 100 to 124 per month in average) and utilization rate of the line was reduced. This affected the overall efficiency of the line. The average changeover time exceeded 15 minutes and the number of people involved in a changeover include four operators and one team leader or supervisor.

The company had some experience in implementing SMED from previous projects, but without the expected success. Lean solutions were applied with a team of two or three people: one lean engineer from the continuous improvement department, the supervisor of the line and maybe one operator or one process engineer. This approach was partially successful due to low involvement of people. Within the present study, for addressing this issue, the team composition for was considered by using “Belbin Roles” theory [13].



Fig. 4. Welding cell layout

The most intensive phase of the project (the implementation phase) was scheduled as a series of workshops with all team members involved. During the first session the team conducted a changeover audit, with

monitoring a number of aspects, such as the sequence of activities, the timing of the different tasks and the motion of all the people involved during the changeover. Based on this audit the tasks for each operator were classified into External, Internal or provisionally to be eliminated. It was also significant to identify different types of waste, such as motion of people and materials as well as waiting time and inventory. Routing diagrams for each operator, showing how the different motions and transportations of materials and tools affect the changeover were drafted as per Coimbra [3].

During the second session, the effort was on building a new changeover standard. Since the welding cell under study involved four operators, instead of just moving external work to the beginning and the end of the standard, there was a need of levelling the different tasks among four operators. Best practices from literature indicate to concentrate all external work in one single operator to minimize overall waste.

A number of additional brainstorming sessions were decided for introducing design based modifications, streamlining and reducing the internal work and finally reducing the external work.

The implementation of the tailored SMED method was rather successful. Since a number of initiatives were implemented gradually, the changeover time at the end of the project was reduced by 33% (fig.5). The annual saving was calculated using the following equation at 13,206€:

$$\left(\text{Annual Saving} \right) = 12 \times \left(\frac{\text{Number of Changeovers}}{\text{month}} \right) \times \left(\frac{\text{Time saved}}{\text{changeover}} \right) \times \left(\frac{\text{Labour}}{\text{Cost}} \right) \times \left(\text{Number of operators} \right)$$

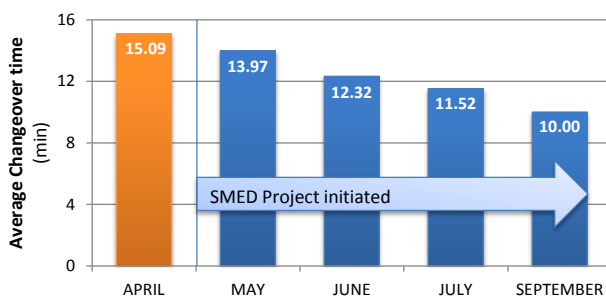


Fig. 5. Changeover time reduction since the beginning of the project

6. Conclusions

In the present paper a tailored SMED methodology was developed. The changes introduced was based on literature review and collection of best practices. The validation of the method resulted in 33% reduction of the changeover time of the welding cell by simply implementing organizational improvements. With the implementation of hardware improvements, reduction of

more than 35% could be achieved. Teamwork and Belbin Roles allocation proved to be very significant. It facilitated the involvement of people from different departments across the organization. Additionally, the project breakdown into four phases allowed separating activities and allocating people to tasks, forcing the progress to occur in an optimal sequence.

Shingo's SMED methodology is not designed for multiple workers with multiple machines since several activities depend on tasks performed previously by others. Within the present study, the proposed method worked well for four operators working simultaneously. An important changeover aspect, the run-up period, has been given attention in this project. The SMED tailored methodology covered the run-up period as part of the changeover reduction strategy.

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